

AutoNAV Across the Solar System (AASS)

Completed Technology Project (2016 - 2019)



Project Introduction

The Deep Space 1 mission showed that a spacecraft can be navigated with minimal ground interaction using images of distant asteroids, planets, and moons. This activity is concerned with quantifying the applicability of this approach to a wide range of deep-space missions, including potential missions to Mars and the outer planets.

The AutoNAV Across the Solar System task will determine what capabilities are needed from an on-board optical orbit-determination system to successfully navigate a variety of mission scenarios with very limited use of DSN radiometric tracking. The Deep Space 1 mission (DS1) demonstrated the feasibility of this approach for deep-space cruise in the inner Solar System; we propose to study the application of this approach across a much broader range of missions. When applicable, this type of on-board navigation approach could dramatically reduce the load on the DSN network for radiometric tracking and the ground personnel man-hours required to navigate the spacecraft. Further, such a system would enable future mission concepts whose demands on DSN tracking and/or navigation personnel far exceed current capabilities (e.g., interplanetary cube-sat missions, formations and constellations, and the NEO-100 concept). The goal of this task is to identify which types of missions are good candidates for an optical-heavy navigation approach and to quantify the expected performance and demands on the spacecraft.

The objective of this task is to quantify the mission characteristics (e.g., fuel for correction maneuvers, camera performance, attitude control system, frequency and number of optical measurements, etc.) required to meet the navigation delivery requirements (i.e., spacecraft position and velocity accuracy) for a variety of scenarios using primarily on-board optical navigation measurements. The goal is to develop requirements on the spacecraft and its camera for each mission scenario that result in a 10x or better reduction in required DSN tracking. These requirements will be compared against current capabilities to assess the feasibility of this approach. The technical foundations of this task are a mix of techniques for orbit determination uncertainty analysis. For the initial and most basic analysis, the instantaneous positioning accuracy that can be achieved with optical measurements has been determined in the FY17 effort as a function of location in the solar system using simple triangulation. This gives a general sense of where an on-board optical system will work best and a rough guide to the orbit determination accuracy that can be expected.

The next step (currently in progress) is to combine measurement information from images taken at different times using a model of the spacecraft dynamics; this is the standard approach to orbit determination. This approach will show how the timing and frequency of the measurements can be used to improve navigation accuracy. It will also reveal when a small amount of radiometric data can be most effect for improving navigation performance. Note that while these analysis techniques are not novel, the idea of using



JPL_IRAD_Activities Project

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almost exclusively optical measurements on-board the spacecraft is a potentially revolutionary approach to deep-space navigation. Before we can invest heavily in this revolutionary technology, we must first understand what it can do.

In FY2017, the work has focused on cruise-phase scenarios where the optical measurement is of the center of some distant object. This includes distant observations of asteroids, planets, or planetary moon systems where the body is less than 1 pixel across in the spacecraft camera. Specifically, we are studying interplanetary cruise scenarios to Mars (using the Insight trajectory) and Jupiter (using the Juno trajectory) to determine what is required of an on-board system to deliver satisfactory orbit determination accuracy. We are also using these same mission scenarios to apply this concept to a Mars orbit insertion and an Earth flyby scenario. In FY2018, the focus will turn toward more complex scenarios, including a Jovian-moon tour and navigation in the Earth-Moon system. In these cases, the orbit determination requirements are more demanding and the moons in the imagery will often be many pixels across (which introduces larger optical measurement errors). In addition to typical day-to-day navigation for these scenarios, we'll also look at flyby targeting, late update, and other less common scenarios where on-board navigation may serve well.

In all cases, the results of the orbit determination accuracy studies will be compared against the navigation delivery requirements for the corresponding mission type (ranges from ~100s – 1000s of km in deep space to a few kilometers for Jovian moon flybys or Mars orbit insertion). In order to determine what characteristics of the on-board system are needed to meet these requirements, the input parameters of the accuracy studies will be tuned until the required performance level is achieved. These parameters include hardware parameters (sensitivity of the camera detector, pixel size, etc.), the amount and timing of radiometric tracking, mission parameters (frequency of navigation imaging, magnitude of un-modeled disturbances on the spacecraft, etc.), and algorithmic parameters (pixel accuracy with which a distant body can be measured, etc.).

The required parameter values to achieve successful navigation will be compared against current and near-future technologies to assess the readiness for implementation on each mission type. In the cases where successful navigation is possible with current technology, the expected range of performance with that technology will be reported. When successful navigation is not currently possible, the gap between current and needed capabilities will be defined. The potential reduction in DSN tracking needs will be quantified.

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

Fred Y Hadaegh

Principal Investigator:

Stephen B Broschart

Co-Investigators:

Shyamkumar Bhaskaran
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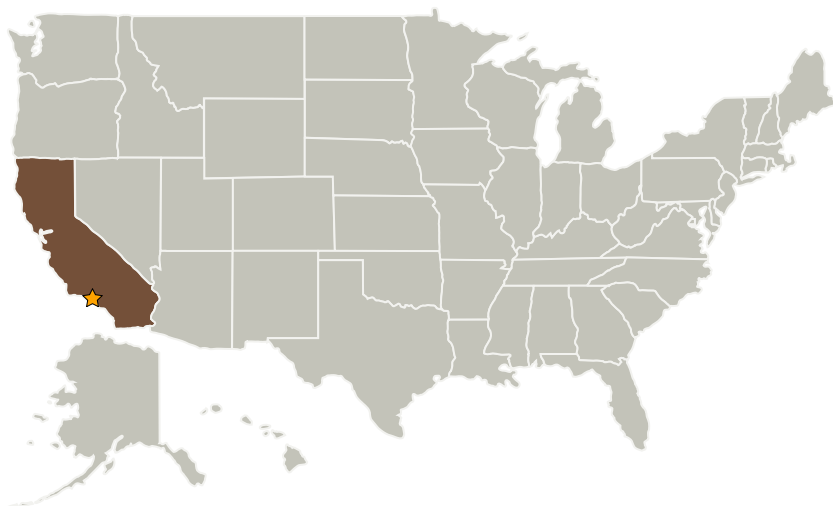
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Anticipated Benefits

On-board optical navigation can dramatically reduce the per-spacecraft need for Deep-Space Network tracking time, enabling support of a larger number of deep-space missions from commercial entities as well as cubesats, constellations, and mother-daughter spacecraft pairs.

Primary U.S. Work Locations and Key Partners



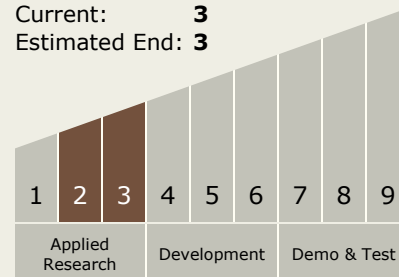
Organizations Performing Work	Role	Type	Location
★ Jet Propulsion Laboratory (JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations

California

Technology Maturity (TRL)

Start: 2
Current: 3
Estimated End: 3



Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
 - TX17.2 Navigation Technologies
 - TX17.2.1 Onboard Navigation Algorithms

Target Destinations

Mars, Others Inside the Solar System, Outside the Solar System

Supported Mission

Type

Push

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Images



JPL_IRAD_Activities Project Image

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(<https://techport.nasa.gov/image/28038>)